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Volume Two / Book 1

Radiology of the skull and brain

ANGIOGRAPHY

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With 4,059 illustrations

The C. V. Mosby Company

Saint Louis 1974

CHAPTER 45

Techniques of catheter cerebral angiography

Thomas H. Newton and Charles W. Kerber

The technique of cerebral angiography has varied greatly since Moniz performed the first successful carotid arteriogram in 1927. Three basic approaches have evolved: (1) direct needle puncture of the vessel to be studied, or a modification thereof with catheter replacement (Chapter 44); (2) puncture of a remote vessel (e.g., brachial artery) with retrograde injection of a large bolus of contrast medium (Chapter 44); and (3) puncture of a remote vessel (e.g., femoral or axillary artery) with selective catheterization of the vessel under study. The last approach is discussed in this chapter.

Historical aspects

The early development of catheter techniques was delayed because of lack of proper catheter material and inadequate fluoroscopic equipment. While performing cardiac catheterization via the radial artery, Radner (1947) inadvertently introduced the catheter into the vertebral artery. He developed this technique of vertebral arteriography and later published an extensive monograph on the subject. Using this technique, Hauge (1954) further expanded the clinical indications for catheter vertebral angiography. Bierman and his colleagues (1951) described a technique of arterial catheterization of the carotid, subclavian, and vertebral arteries, after introduction of the catheter into the surgically exposed femoral artery. Seldinger's description in 1953 of percutaneous introduction of the catheter led to routine nonsurgical techniques for catheter cerebral angiography. Not until 1956, however, did Odman describe the percutaneous femoral catheter approach to the innominate and subclavian arteries. Since then catheter techniques have been employed relatively widely for vertebral angiography and their value for this procedure has been emphasized (Lindgren, 1956; Bonte et al., 1958; Cronqvist, 1961; Scatliff et al., 1965; Newton et al., 1966; Takahashi et al., 1968, 1969; Schechter and de Gutiérrez-Mahoney, 1973). Westcott and his coworkers (1963), as well as Milne (1964), reaffirmed Odman's approach and described their experiences with transfemoral catheterization of all brachiocephalic vessels. Since then several reports have stressed the value of femoral catheter techniques in carotid angiography (Amundsen et al., 1967; Hare, 1967; Hinck et al., 1967; Chynn, 1969; Takahashi and Kawanami, 1970). In 1966 Newton and Kramer showed the value of this technique for selective external carotid arteriography. The technique was also successfully applied to cerebral angiography in children by Newton and Gooding (1968) and Takahashi and Kawanami (1971).

The widely accepted "head hunter" curves, which Hinck and his colleagues (1967) devised, require a relatively large stiff catheter with a wire braid in its wall for better torque control. This catheter may be placed in the proximal brachiocephalic vessels, but we believe it is dangerous when more selective catheterization is attempted. Mani (1970) described a smaller catheter of greater flexibility and with similar head hunter curves for more selective transfemoral catheterization of all brachiocephalic vessels.

The technique of cerebral angiography selected depends on the experience and training of the angiogra-

pher as well as on the design of the angiographic room (Hinck and Dotter, 1969). Selective transfemoral catheterization of brachiocephalic vessels must be performed only by well-trained physicians who know the importance of meticulous technique necessary for successful studies with minimum complications. This technique should not be performed unless the passage of the catheter can be observed easily by image-intensified fluoroscopy. Although optical image intensification is satisfactory, monitoring by television is recommended. When such monitoring is available, the procedure may be performed in a well-lighted room. Horizontal fluoroscopy, although useful in some instances, is not necessary. A simple angiographic table with a floating tabletop is a second requirement for successful catheter angiography. The tabletop excursion must be sufficiently long to enable fluoroscopy of the patient from the groin to the head. Once the catheter has been advanced into a particular vessel, a simple and rapid method must be available to place the patient's head over the rapid film changer. An angiographic table with a variable height of the tabletop allows a comfortable working level for the operator and permits magnification techniques in the frontal projection.

We have employed the transfemoral catheterization technique in all cerebral angiographic procedures since 1965. Many minor modifications in the technique since then have greatly simplified this approach. In this chapter we limit our description to our present technique and do not describe the many modifications proposed by other authors.

Advantages of catheter technique

Transfemoral cerebral catheter angiography has the following advantages:

1. Puncture of the femoral artery and introduction of a catheter by this route are simpler than via the brachial, axillary, or subclavian arteries because the femoral artery is larger. In most patients manipulation of the catheter into the carotid or vertebral arteries is relatively simple.

2. Direct puncture of the carotid artery and manipulation and compression of the neck area, an unpleasant and often frightening experience for the patient, are avoided. Mild sedation and local anesthetic of the puncture site are usually adequate even in agitated or apprehensive patients. A general anesthetic with its attendant risk and morbidity is therefore rarely needed.

3. The arterial puncture is at a site where any local complications that do occur are less urgent and can be managed readily. Spasm, thrombosis, intimal dissection, arteriovenous fistulae, and hematoma may occur with any arterial puncture. The risk of disastrous complications related to the arterial puncture is therefore higher with direct carotid or vertebral arteriography. Avoidance of direct carotid puncture is particularly important in patients with cerebrovascular insufficiency, in whom vascular trauma from the procedure could further compromise an already deficient blood supply. In these patients damage to the carotid or vertebral artery, e.g., dislodgement of a plaque, subintimal injection, or extravascular hematoma, can lead to serious neurologic complications. The carotid artery, when studied by transfemoral catheterization techniques, is not surrounded by a hematoma, as is invariably noted with direct-puncture techniques. Surgical correction of arteriosclerotic stenosis of the carotid arteries is therefore greatly simplified when angiography has been performed with the transfemoral catheter technique.

4. Patient mobility for angiography in various positions is not restricted since the position of the catheter within the lumen of the vessel is easily maintained. Extravascular or subintimal injections are rare and injections can be repeated.

5. All the brachiocephalic vessels, as well as the aortic arch itself, can be examined after puncture of a single vessel when the transfemoral technique is employed. The entire vessel, including its proximal portion, can be examined. Selective opacification of the internal or external carotid artery, the vertebral artery, or other branches of the subclavian artery is possible with this technique. As in other peripheral arteriographic examinations, selective opacification of a specific circulatory bed greatly enhances the angiographic detail. The transfemoral cerebral catheter technique thus permits a more detailed and specific analysis of many neuroradiologic problems and is particularly indicated when more than one vessel is to be studied. In an investigation of subarachnoid hemorrhage, for instance, all cerebral vessels can be selectively opacified during one examination and the study completed more quickly than with direct-puncture techniques.

6. When performed with modern techniques, complications of transfemoral cerebral angiography are few (Takahaski and Kawanami, 1972; Pollock, to be published). (See Chapter 53.)

7. The transfemoral catheter technique provides maximum flexibility of operation for the angiographer. An examination may be planned in advance and modified according to the angiographic findings noted at the time of the study.

Disadvantages of catheter technique

The disadvantages of the catheter technique are as follows:

1. The roentgenographic equipment must be somewhat more elaborate than that needed for direct-

puncture technique. Fluoroscopic equipment and a floating tabletop must be available.

2. The radiologist must be more experienced and skillful to perform catheter angiography if complications are to be avoided. For this reason physicians who are not experienced in the use of catheters should either obtain the necessary training in this approach or use the simpler direct-puncture techniques.

3. The risk of embolization is slightly higher during manipulation of the catheter, particularly if careful flushing techniques are not employed, or if catheters with side holes are used.

4. The catheters and wires are more expensive than simple needles.

CATHETERS

The catheter used for transfemoral catheterization of the cerebral vessels requires the following characteristics: (1) it should be thin walled (i.e., have a small outer diameter relative to a large inner diameter); (2) it should be relatively soft to avoid intimal damage or perforation of an artery; (3) it should have good torque control so that rotation of the tip of the catheter will respond to rotation at the puncture site; (4) shaping of it into various curves should be simple and it should have a good "memory" for these curves (i.e., retain the curve during the examination); (5) it must be strong enough to withstand the pressure and flow rates necessary for satisfactory angiography; (6) if possible, it should be slightly radiopaque; (7) its surfaces should be smooth and nonthrombogenic (Amplatz, 1971; Björk, 1972; Schlossman, 1973); (8) sterilization of the catheter material must be simple; and (9) it should be relatively inexpensive and disposable after one use (Olin, 1963; Krovetz et al., 1966; Susman and Diboll, 1969; Glancy et al., 1970).

For selective catheterization of cerebral vessels, particularly in older patients, the catheter must meet two opposing conditions: (1) it must be stiff enough to maintain the preselected curve so that a guide wire can be passed through it without dislodging it from the orifice of the vessel; (2) it must be soft and flexible enough, however, to be advanced over the guide wire around sharp bends even though its tip is shaped into a compound curve. The physical characteristics of various plastic catheters are shown in Table 45-1.

In our experience a polyethylene catheter manufactured by Becton-Dickinson (RPX 045H)* with an inner diameter of 0.045 inch (1.15 mm) and an outer diameter of 0.065 inch (1.65 mm) meets most of the criteria. This catheter is only slightly radiopaque and must be filled with contrast medium to be visualized easily. It is thin walled, can be shaped easily with steam, and has fairly good torque control. Its memory for curves is fair, the curves tending to open up after exposure to body heat for 20 minutes or more. The catheters can be purchased in coils of 100 feet. Before sterilization they are cut into 100 cm lengths. Their tips are tapered by gently pulling one end (Fig. 45-1, *A*). The tapered end is then cut with a sharp blade (Fig. 45-1, *B*) so that it fits snugly over the guide wire (*C*). The other end is flanged over low heat (Fig. 45-1, *D*). The catheter is then placed in a clear nylon bag* and sterilized by exposure to ethylene oxide gas. Sterilized preshaped catheters, complete with fittings, are now also available.† We do not use presently available tip controlled catheters recommended by some authors (Rabinov and Simon, 1969).

A stopcock adaptor is placed on the catheter immediately before the angiographic procedure. The end of the catheter is then curved by steam (Fig. 45-2). The tip must not be exposed to steam, to prevent expansion of the tapered segment. The type of curve depends on the vessels to be studied and the age of the patient. The most commonly used curves are shown in Fig. 45-3.

Different portions of curves

The tertiary curve of the catheter is already in the catheter. Catheters rolled in coils at the time of manufacture have a basic tendency toward this original curve. This original (or tertiary) curve will follow the arch of the aorta, and any curve placed opposite this curve tends to enter the brachiocephalic vessels. In children and young adults a simple primary curve at an angle of approximately 45° to 90° to the tertiary curve usually permits easy catheterization of all brachiocephalic vessels. In older patients in whom the aortic arch is elongated, a secondary curve is necessary to engage the orifice of the brachiocephalic vessels (Fig. 45-3).

GUIDE WIRES

The technique of transfemoral cerebral angiography depends on the availability of guide wires that not only permit the percutaneous introduction of the catheter into the artery but also aid in the positioning of the catheter into the particular vessel under study.

History of guide wires

In the middle and late 1950's Kifa, a Swedish manufacturer, produced the first commercially available guide

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*Becton-Dickinson, Rutherford, N. J. 07070.

*B thickness nylon autoclavable film (1,000 ft roll) available from Vail Medical Products, Inc., 1617 Grand Ave., Los Angeles, Calif. 90015.

†Cook, Inc., Box 489, Bloomington, Ind. 47401, and Universal Medical Instrument Corp., Box 100, Ballston Spa, N.Y. 12020.

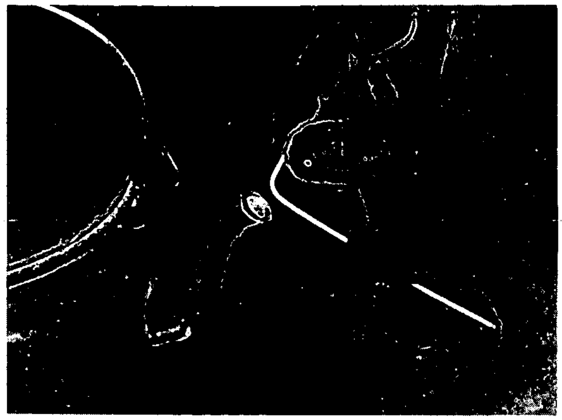


Fig. 45-2. The tip of the catheter is shaped by exposure to steam.

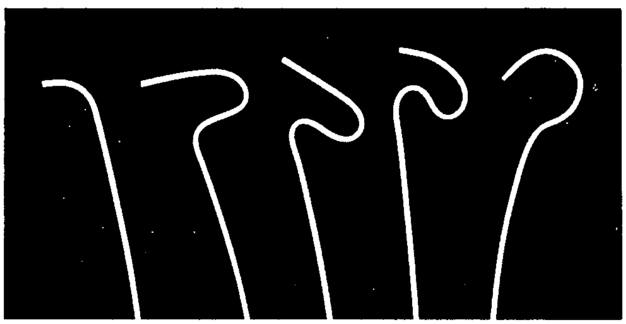


Fig. 45-3. Catheter shapes used for cerebral angiography. The catheter on the left is used for young patients; the others for older patients.

wires (Cook, 1972). Not until 1962, however, did domestic manufacturers such as Becton-Dickinson, U. S. Catheter & Instrument Company, and Cook, Incorporated, begin to produce such wires—essentially copies of the original Kifa type. Major problems were associated with these early guide wires. At first, only the spring tension placed in the coils by twisting the wires during coiling prevented the guide from pulling apart when a tug or pull was applied to it. Early guide wires required only 1.5 to 2 lb to permanently deform the spring coil since they contained no safety wire to prevent coil separation. The ability of the coils to stay together during flexion or tension depended on a relatively large diameter of the steel wire, which in turn made the spring coils coarse. The coils were soldered at one end to an internal stiffening wire (mandrel or core), which furnished rigidity or body to the guide wire, and a solder ball was attached at the distal tip to cover the rough edge of the wire. The mandrel was not tapered, and consequently the coils tended to kink at the termination of the blunt mandrel when the flexible end was pushed around an acute angle in the vessel. This kink occasionally resulted in breakage of the wire (Cope, 1962; Halpern, 1964). Such breakage was probably the result of either flaws in the base metal or kinking of the wire.

Chemical and physical characteristics of stainless steel wire as related to guide wires

Stainless steel is used in the manufacture of guide wires because of its strength and ability to resist corrosion. The extent of corrosion can be limited somewhat by the deposition of a thin film of oxide on the wire immediately after fabrication and by minimizing defects during wire manufacture with new production techniques and strict quality control. If oxide does not coat the stainless steel, or if the coating is penetrated by a chemical or mechanical score or mark, the corrosive process begins and eventually the wire may break down completely. One of the strongest agents that attack stainless steel is the chloride ion of blood.

When bent back and forth many times, stainless steel eventually becomes brittle and breaks from fatigue. This process is called work hardening and is characteristic of many ferrous-type metals. The hardened metal is then subject to another type of phenomenon called stress corrosion, evidenced by a change in molecular structure of the wire. The wire not only becomes brittle but is more susceptible to chemical attack by chloride in the blood even though the oxide coating was applied at the time the coil was made.

Guide wire improvements

A second internal safety wire is now placed tip-to-tip inside all modern guide wires to prevent separation of coils and to minimize wire breakage (Dotter et al., 1966). Improved metal-joining techniques using silver solders, which do not contain corrosive flux, are now employed in addition to heliarc welding to reduce wire failure. The internal core or mandrel in earlier guide wires was either blunt or tapered over its distal 5 cm. A sharp transition in the flexibility between the distal "floppy" tip and the wire that contained the inner core was characteristic of these standard guide wires. With this guide wire, attempts at catheterization of the brachiocephalic vessels in older patients was often unsuccessful. In older patients a compound catheter curve is necessary to engage the orifice of the brachiocephalic vessels. Unlike the simple curved catheter used in younger patients, this compound catheter curve cannot be advanced into the vessel without the aid of a guide wire. When a standard guide wire (either with or without a movable inner core) is used, the distal floppy coil traverses the distal double curve of the catheter without distorting the catheter's shape or dislodging the catheter from the vessel. The guide wire containing the stiffer inner core must also be passed around the curved tip of the catheter. It must be introduced into the brachiocephalic vessel so that enough support is given to allow the catheter to be advanced over the wire. Usually the standard guide wire cannot be advanced

Preangiographic orders

1. Regular diet on day preceding study
2. Clear liquids on day of study up to time of examination
3. Shave both groins
4. When called from neuroradiology department:
   a. Patient to void
   b. Nembutal 50 mg I.M.
   c. Benadryl 50 mg I.M.
   d. Remove dentures

To avoid dehydration, which may increase the risk of hypotensive episodes, the patient is encouraged to drink clear liquids up to the time of the study. An intravenous infusion of 5% dextrose and water is started when the patient reaches the angiographic suite. Isotonic saline or 5% dextrose in half-normal saline solution is recommended for patients with increased intracranial pressure (Fishman, 1971). Electrocardiographic monitors are used when indicated. A baseline blood pressure and the strength and location of the pedal pulse are recorded. A radiolucent air-mattress,* which alternately inflates and deflates, has proved valuable for prevention of discomfort and backache. These mattresses, measuring 25 × 74 inches, fit the angiographic tables. Scout films are usually obtained and the patient's groins are then prepped and draped.

The blood pressure is monitored closely throughout the examination. Should hypotension occur, it is treated by the Trendelenburg position or, should this fail, by a slow intravenous infusion of 20 mg of metaraminol (Aramine) in 250 ml of saline. The avoidance of hypotensive episodes, which reduce cerebral blood flow, is particularly important in patients with symptoms related to cerebrovascular insufficiency.

*Gaymar Industries, Inc., 701 Seneca St., Buffalo, N.Y. 14210.

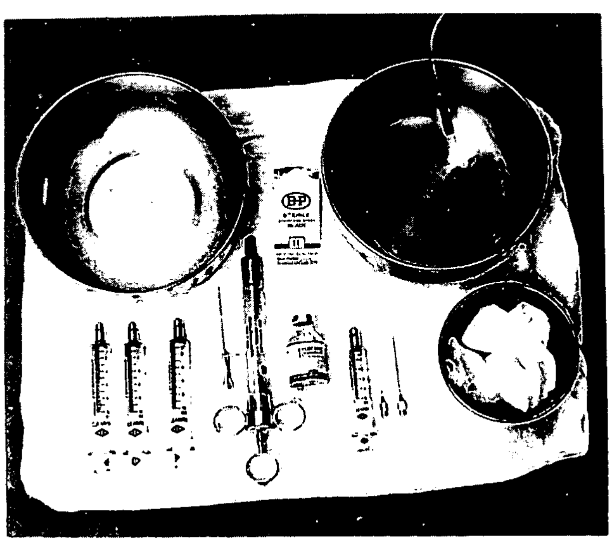


Fig. 45-5. Contents of a cerebral angiographic tray.

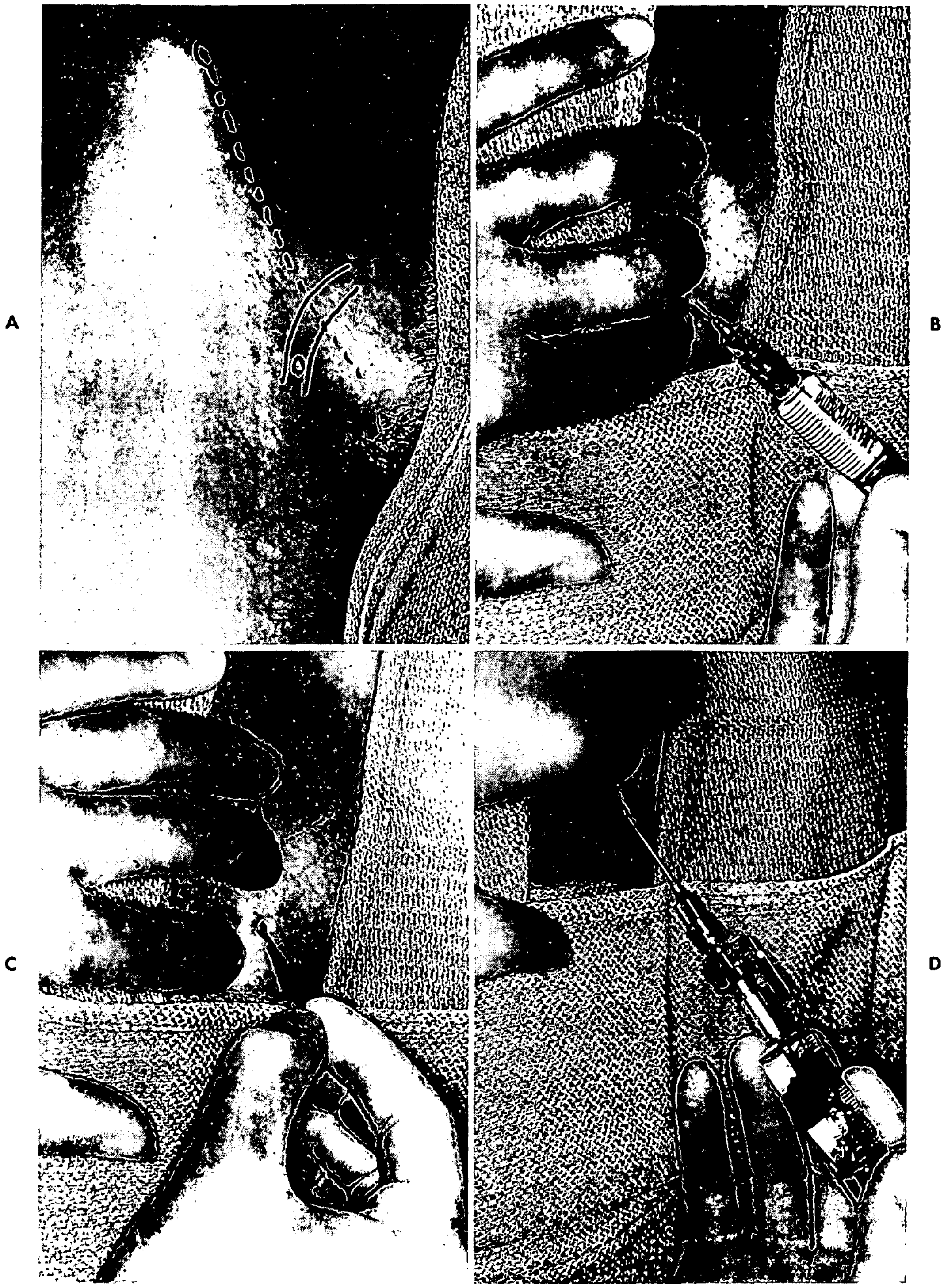
Angiography tray

The contents of the tray for cerebral angiography are shown in Fig. 45-5. Syringes of different sizes should be used for the local anesthetic, the flushing solution, and the contrast medium so that inadvertent substitution of syringes is avoided. A closed system for the flushing solution (heparinized saline solution, 4,000 units heparin per liter of saline) is used to avoid contamination (Adams et al., 1965; Mishkin, 1966).

Arterial puncture and introduction of catheter

The femoral artery is palpated 3 to 4 cm below the inguinal ligament (Fig. 45-6, *A*) and the skin is infiltrated with 1 to 2 ml of 1% lidocaine by means of a 25-gauge needle (Fig. 45-6, *B*). An additional 6 to 8 ml of the local anesthetic are then injected deeper into the soft tissues adjacent to the femoral artery with a 23-gauge needle. Aspiration before each injection to avoid intravascular introduction of local anesthetic is important. A small incision is then made in the skin to facilitate the later passage of the catheter (Fig. 45-6, *C*).

The femoral artery is located by palpation with the fingers of the left hand. An 18-gauge thin-walled needle is introduced through the skin incision at an angle of approximately 45° with the skin. If the puncture is too high or the needle is introduced at a very oblique angle, the peritoneal cavity can be entered. Hemorrhage into the peritoneal cavity may result. The needle is then advanced gently with the right hand to the surface of the femoral artery, where transmitted pulsations can be felt. It is then farther advanced to puncture the femoral artery. When a needle with a stylet is used, both the anterior and the posterior walls of the vessel are usually punctured. The stylet is then removed and the needle is depressed slightly and withdrawn slowly until the spurt of pulsatile blood from the needle indicates its position within the lumen. A single-wall puncture technique may be employed with an 18-gauge thin-walled needle attached to a stopcock and a syringe half filled with heparinized saline solution. The needle is placed on the anterior wall of the artery with the bevel up and then advanced slowly through the anterior wall into the arterial lumen. If the palpating fingers of the left hand have compressed the artery excessively, the needle may pass through both walls. The needle should then be rotated 180° so that the bevel faces downward. The hub of the needle is then slightly depressed and the needle slowly withdrawn. Spurting of blood into the syringe indicates the needle's proper position within the lumen of the vessel (Fig. 45-6, *D*). The flexible distal tip of the guide wire is then introduced



Continued.

Fig. 45-6. Method of arterial puncture in catheter introduction. A, The position of the inguinal ligament is indicated by a dotted line, and the course of the femoral artery by solid lines. The site of the skin puncture is indicated by the circle. B, The skin is infiltrated with 1% lidocaine. C, A small nick in the skin is made with a no. 11 knife blade. D, The anterior wall of the femoral artery is punctured with an 18-gauge thin-walled needle. E, A guide wire is gently introduced through the needle into the abdominal aorta. F, The needle is withdrawn while the puncture site is compressed with the fingers of the left hand. G, The catheter is introduced over the guide wire into the femoral artery.

E

F

G

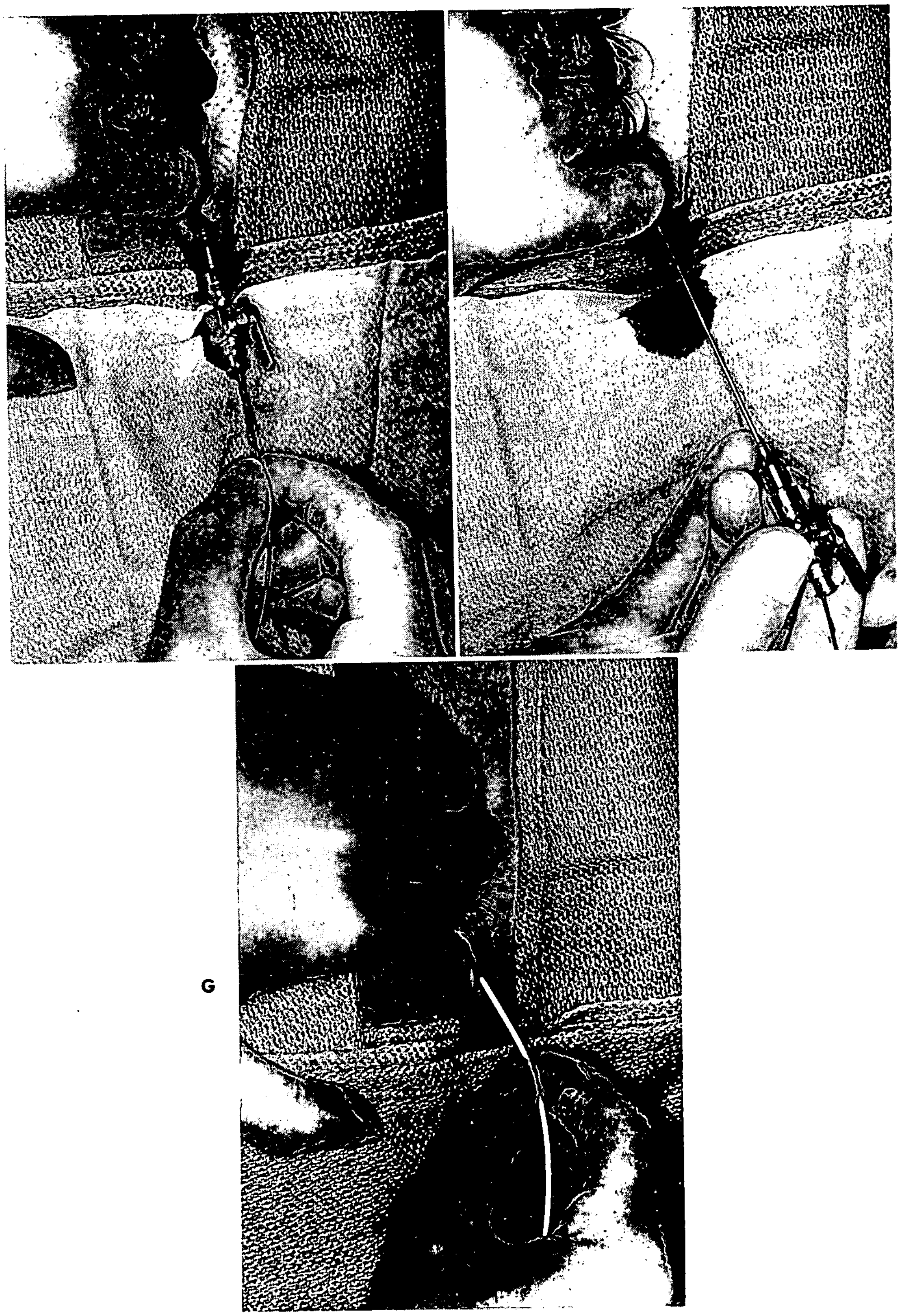


Fig. 45-6, cont'd. For legend see p. 927.

gently through the needle, and the wire is advanced into the abdominal aorta under fluoroscopic control (Fig. 45-6, *E*). The guide wire should pass up easily without hindrance or obstruction. Difficulty in passage of the guide wire may be the result of arteriosclerosis or elongation of the iliac arteries, or it may be caused by improper position of the needle within the lumen of the vessel. The guide wire should then be removed to check on the pulsation of the arterial back flow to ensure that the needle is truly within the lumen of the vessel. The use of J-tipped guide wires often facilitates their passage through a tortuous iliac artery. Occasionally the guide wire cannot be advanced into the aorta because it has entered a side branch. The guide wire should then be repositioned into the main arterial lumen under fluoroscopic control, whereupon it can again be advanced without hindrance.

When the guide wire has been advanced into the abdominal aorta, the needle is withdrawn and the arterial puncture site is compressed with the third, fourth, and fifth fingers of the left hand while the guide wire is grasped with the index finger and thumb of that hand (Fig. 45-6, *F*). The guide wire is then wiped with a wet sponge, and the catheter is advanced over the guide wire by an assistant until it reaches the puncture site in the skin. The catheter and the guide wire are then advanced into the femoral artery (Fig. 45-6, *G*). The catheter is farther advanced while the guide wire is slowly withdrawn.

Flushing of catheter

As soon as the guide wire has been withdrawn from the arterial catheter, the catheter is flushed intermittently. Most complications related to catheter angiography are caused by emboli. Therefore the catheter must be flushed vigorously and frequently. We use an intermittent flushing technique in which 2 to 3 ml of blood are aspirated from the catheter about every 2 minutes. A second syringe filled with heparinized saline is then attached, and approximately 5 ml of saline are injected rapidly through the catheter. At the end of this injection, the stopcock is closed immediately to prevent reflux of blood into the catheter tip. Before any injection of flushing solution or contrast medium, slight aspiration is important to clear air bubbles that are frequently present at the connection between the syringe and the stopcock. Systemic heparinization has recently been recommended to decrease the complications of catheter angiography related to thrombosis (Wallace et al., 1972).

Manipulation of catheter

After its advancement into the lower thoracic aorta, the catheter is filled with contrast medium to enhance its visualization. It is then slowly advanced into the aortic arch.

In *children and young adults* up to the age of about 45 years, a simple curve is used (Fig. 45-3). The position of the distal tip can be altered by rotating the catheter gently at the site of arterial puncture. In younger patients the catheter tends to enter the left subclavian artery, and advancement of the catheter into the ascending arch of the aorta may be difficult. In these cases an open J-tip guide wire helps to direct the catheter past the subclavian artery into the ascending arch. Once the catheter is in the ascending arch of the aorta, it is pulled back slightly and rotated so that its tip points superiorly to engage the innominate artery. Advancement is then simple, and usually the catheter enters the right common carotid artery. The head of the patient is turned to the left to separate the internal and external carotid arteries. Under fluoroscopic control and with small test injections of contrast medium, and by pointing either posteriorly or anteriorly, the catheter can be maneuvered into either the internal or the external carotid artery respectively. Entry into the internal carotid artery is facilitated by flexion of the patient's neck, and into the external artery by extension of the neck. The left common carotid artery is usually entered easily by withdrawing the catheter slowly from the innominate artery and pointing the tip toward the left. The tip of the catheter usually snaps out of the innominate artery and enters the left common carotid artery with ease. Usually then the catheter is advanced without the use of a guide wire into the common carotid artery and selective placement of the catheter in the internal and external carotid arteries is accomplished as on the right side.

Opacification of the vertebral system is usually most easily accomplished on the left. The catheter is withdrawn into the descending arch of the aorta and is then advanced with the tip pointed toward the left. The left subclavian artery is usually entered with ease. A small amount of contrast medium is injected to opacify the origin of the left vertebral artery. The catheter is then slightly rotated so that its tip points medially. Advancement of the catheter in this position usually engages the left vertebral artery. As soon as the left vertebral artery has been entered, a small amount of contrast medium should be injected to verify the catheter's position. In patients in whom the left vertebral artery is unusually small and the runoff of contrast medium inadequate, the catheter should be withdrawn immediately. Attempts at catheterization of the right vertebral artery can then be begun. In these patients the catheter is advanced into the innominate artery as described before. The catheter is then rotated slightly so that its tip points to the right and tends to enter the

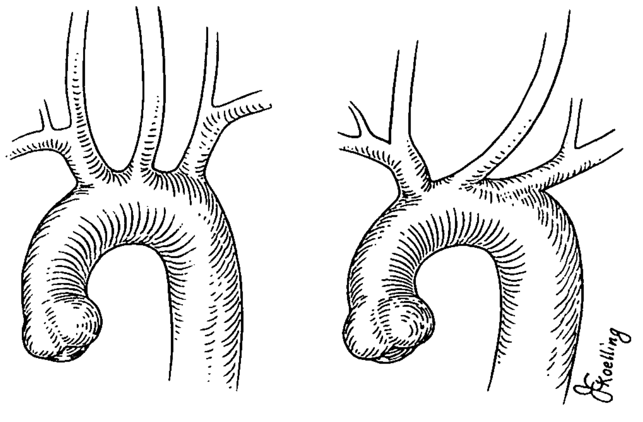


Fig. 45-7. Diagram of the aortic arch and brachiocephalic vessels. A, Young adult. The left subclavian artery forms an almost straight line with the descending thoracic aorta. The remainder of the brachiocephalic vessels arise at almost right angles from the aortic arch. B, Older patient. The aortic arch has become elongated, causing the brachiocephalic vessels to enter the aortic arch at a more acute angle.

right subclavian artery. Once it is in the subclavian artery, a small amount of contrast medium is again injected to locate the orifice of the right vertebral artery. By rotating the catheter so that its tip points superiorly, one can maneuver it into the right vertebral artery. The catheter is usually advanced 2 to 3 cm into the vessel to prevent its recoil out of the artery during injection of the contrast agent.

In *older patients,* in whom the aortic arch is elongated and in whom the brachiocephalic vessels leave the aortic arch at a more acute angle, a compound curved catheter must be employed (Vitek, 1973) (Figs. 45-3 and 45-7). The catheter is advanced into the ascending arch of the aorta and opacified with a small amount of contrast medium. Because the catheter tends to straighten and lose its curve during the examination, the left common carotid artery, the most acutely angled vessel, is usually examined first. The orifice of the left common carotid artery may be engaged in either of two ways: (1) The catheter is first advanced into the ascending arch of the aorta. It is pointed upward and then pulled back slowly to engage the innominate artery. By means of a small test injection, the origin of the left common carotid artery, either from the innominate artery or directly from the aorta, may be determined. The catheter is then withdrawn slowly and rotated so that its tip faces superiorly and anteriorly. In leaving the innominate artery the tip then usually springs into the orifice of the left common carotid artery (Fig. 45-8, *A*). (2) The left subclavian artery can be engaged first. When the catheter is advanced slowly, it tends to snap out of the subclavian artery and enters the left common carotid artery. It is then withdrawn slightly to seat it well within the proximal common carotid artery. After the tip has been placed in the proximal left common carotid artery, a guide wire with a tapered inner core (SF 35-135X LT, Cook, Inc.) is introduced through the catheter and advanced through the compound curve into the common carotid artery (Fig. 45-8, *B*). As indicated previously, a smooth transition between the flexible tip of the guide wire and the stiff inner core is important. The stiffer portions of the wire can then traverse the compound curve and not thrust the catheter back into the ascending arch of the aorta. Once the stiffer portion of the guide wire has traversed the compound curve, the catheter can be gently advanced over the guide wire. At this point the proximal guide wire is anchored against the leg of the patient by an assistant, care being exerted not to advance the wire farther up through the carotid bifurcation. Rotation of the catheter before it is advanced straightens the compound curve and facilitates the upward passage of the catheter (Fig. 45-8, *C*). After the catheter has passed up into the carotid artery, the guide wire is withdrawn (Fig. 45-8, *D*). The catheter is then immediately flushed and its position checked by a small test injection of contrast medium. If the carotid bifurcation is normal, the guide wire can be reintroduced and maneuvered into either the internal or the external carotid artery. The catheter can then be advanced farther into one of these branches for selective internal or external carotid arteriography.

Examination of the right common carotid artery is similar to that for the left and is usually accomplished by first engaging the catheter tip in the innominate artery and passing a guide wire through the curve. Further passage usually causes the guide wire to enter the right common carotid artery. The catheter is then advanced over the guide wire as described for the left common carotid artery.

For left vertebral arteriography the catheter is withdrawn into the proximal descending aorta. It is then advanced with its tip pointing slightly to the left, whereupon the left subclavian artery is engaged. The guide wire is then advanced into the subclavian and axillary arteries and the catheter advanced, after which the guide wire is withdrawn and the catheter is flushed. The catheter is then withdrawn gradually until it engages the orifice of the left vertebral artery. The guide wire is then advanced into the vertebral artery, and the catheter is slowly threaded over the wire and pushed into the vertebral artery for several centimeters.

If the catheter cannot be securely seated in the orifice of the vessel to be studied, its curve is probably incorrect for that particular anatomic configuration. It

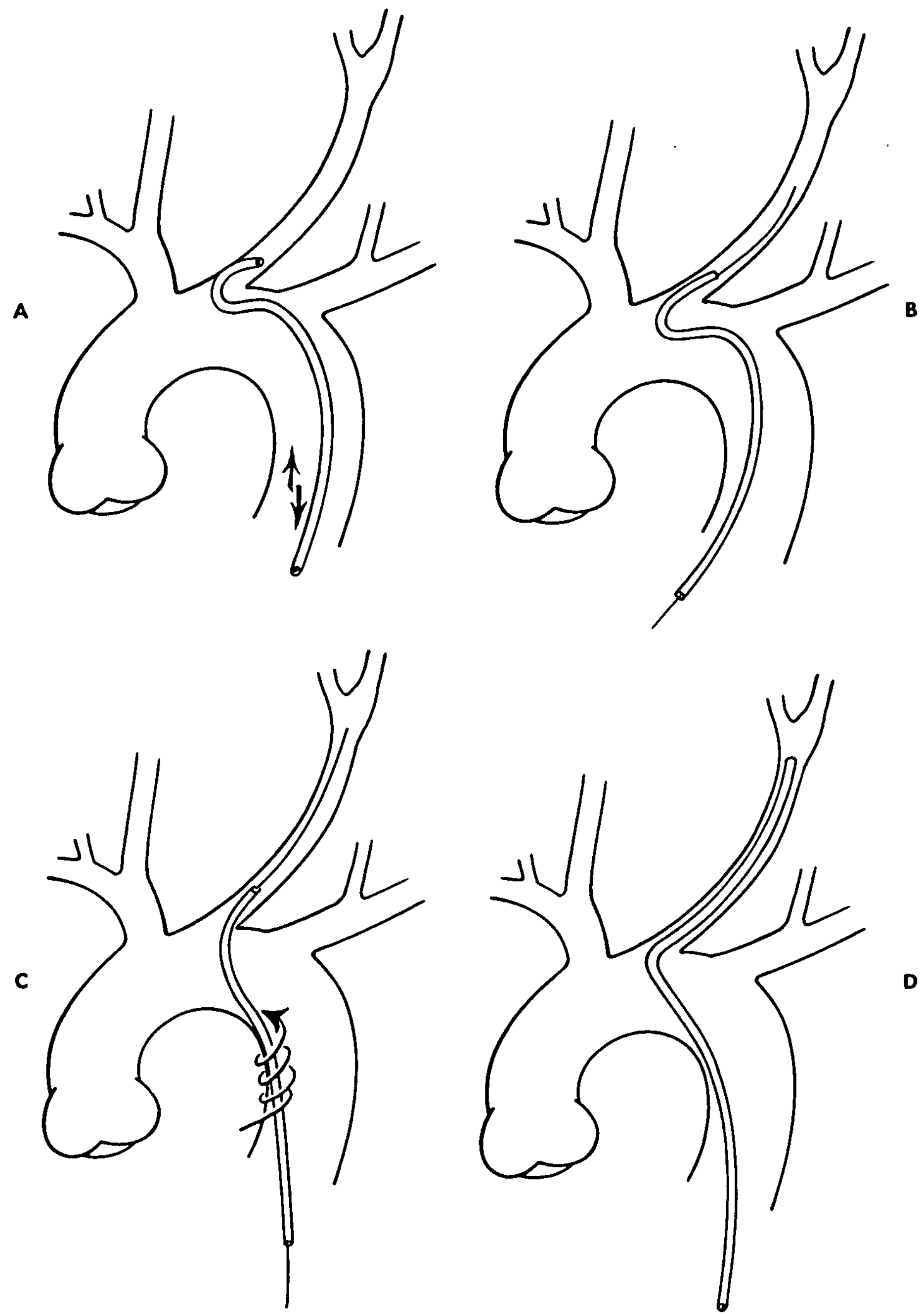


Fig. 45-8. Diagram showing the technique of catheterization of the left common carotid artery in an older patient. **A,** The tip of the compound curved catheter is hooked into the orifice of the left common carotid artery. **B,** A tapered guide wire is advanced through the catheter into the common carotid artery. **C,** The catheter is advanced over the guide wire into the common carotid artery using rotation and gentle forward motion. **D,** The guide wire is withdrawn and the catheter is flushed.

Table 45-2. Type of catheter and rate of injection used in patients according to their weight

Patient's weight	*<5 kg*	*5-20 kg*	*>20 kg*
Needle	21-gauge	19-gauge	18-gauge
Guide wire	0.018 in.	0.025 in.	0.035 in.
Catheter	Becton-Dickinson {I.D. 0.025 in. O.D. 0.041 in.	Becton-Dickinson (RPX 037H) {I.D. 0.037 in. O.D. 0.054 in.	Becton-Dickinson (RPX 045H) {I.D. 0.045 in. O.D. 0.065 in.
	Cook (Pert 3.0) {I.D. 0.022 in. O.D. 0.040 in.		
Contrast medium (maximum total 4-5 ml/kg)			
Internal carotid artery	4 ml/sec for 1.2 sec	5 ml/sec for 1.2 sec	7 ml/sec for 1.2 sec
Vertebral artery	3 ml/sec for 1 sec	4 ml/sec for 1.2 sec	5 ml/sec for 1.2 sec
Common carotid artery	5 ml/sec for 1.2 sec	6 ml/sec for 1.2 sec	8-9 ml/sec for 1.2 sec

should then be exchanged for one with a more suitable curvature.

Contrast medium injection and roentgenography

Automatic pressure injection is employed in all patients, not only to avoid radiation exposure to the angiographer but also to obtain reproducible rates of injection. The pressure injector should deliver a predetermined dose of contrast medium in a given time regardless of the length of the catheter or the viscosity of contrast medium. Both the Viamonte-Hobbs* and the Medrad† injectors have proved satisfactory in our department. When connecting the arterial catheter to the injector, one must be careful that air bubbles do not enter the system. A short, clear Teflon connecting tube is attached to the automatic syringe, from which all air bubbles are expelled. The arterial catheter is then flushed by the two-syringe flushing technique described previously. Before forward flushing with the second syringe, a small amount of blood is drawn into the heparinized saline and the forward flush then causes the catheter to be filled with slightly blood-tinged saline solution. When the syringe is removed from the stopcock, a small amount of pressure is maintained on the plunger so that the meniscus of this blood-tinged heparinized saline remains on the stopcock. The stopcock and the Teflon tubing attached to the pressure syringe are then connected. The slightly blood-tinged saline forms an interface with the contrast material. When the stopcock is opened, the interface moves slightly toward the Teflon tubing and any air bubbles can be easily identified. About 1 minute is required to connect the catheter to the injector. During that time the technician should complete the positioning of the patient so that when the catheter has been connected to the pressure injector the contrast medium can be injected and angiography be started. The amount of contrast medium and rates of injection are shown in Table 45-2. The program is set up so that an initial roentgenogram is obtained for subtraction purposes 0.6 second before the injection of the contrast medium is begun.

For carotid arteriography the routine views include lateral and frontal projections. Vertebral arteriograms are studied routinely by magnification techniques in the lateral, Towne, and straight frontal projections. In addition, angioautotomography is employed when masses in the posterior fossa are suspected (Chapter 50). In adults a series of two roentgenograms per second are obtained for the first 4 seconds and then one roentgenogram per second for the next 6 seconds. In children the exposures are usually two per second for 3 seconds followed by one per second for 4 seconds. The series is prolonged in patients with intracranial hypertension.

Postangiographic care

After the angiograms are checked and found to be technically satisfactory, the pedal pulses should again be checked. The catheter is then slowly removed with the right hand and pressure is applied to the femoral artery at the puncture site with the fingers of the left hand. The pressure should be adequate to stop bleeding but not so strong as to completely occlude the vessel. This latter point is particularly important in children, in whom thrombosis of the femoral artery may follow overzealous compression of the arterial puncture site. Direct pressure should be maintained for 10 to 20 minutes in adults. A longer time may be necessary in hypertensive patients. In children pressure applied for approximately 10 minutes is usually satisfactory. In all instances the patient remains in the radiology department for at least 30 minutes and is watched closely for any evidence of bleeding or other complications. No dressing should be applied to the puncture site so that any bleeding after the patient has been returned to the ward can be observed immediately and treated by direct compression of the puncture site.

*Barber-Coleman Co., Rockford, Ill. 61101.
†Medrad, Inc., 566 Alpha Dr., Pittsburgh, Pa. 15328.